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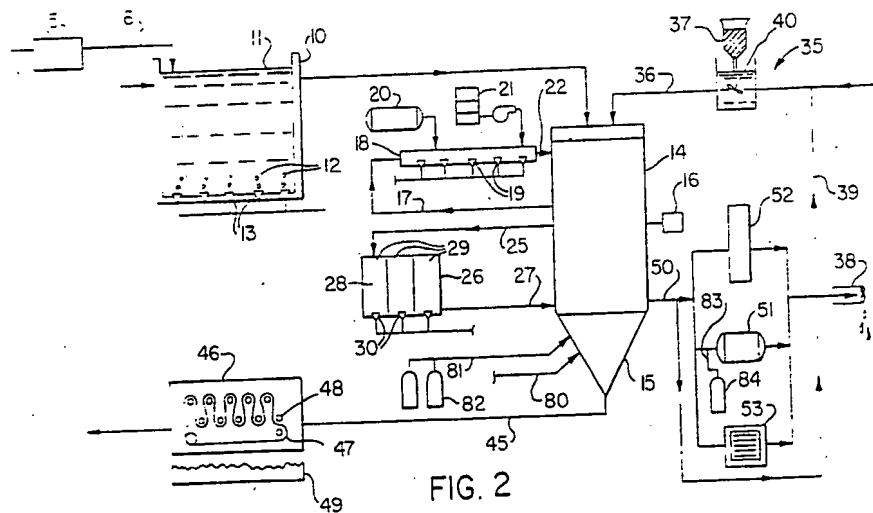
C1C

Selected US specifications from IPC sub-class

C02F

(54) Process and apparatus for the purification of water

(57) A process for treating waste water so that it may be safely discharged into the environment or re-used comprises acidifying the water to a pH of 3.5 or lower, contacting the acidified water with metallic iron, separating the water from the iron, rapidly making the iron-treated water alkaline to a pH of 9.0 or more and separating the water from any precipitate or flocculate formed therein. Water in a tank 14 is acidified in a chamber 18 and passed over iron pieces in a chamber 26. Lime is added via a pipe 36. The precipitate or flocculate is withdrawn through a pipe 45. The water is aerated through nozzles 13, 19 and 30. The apparatus is preferably manufactured in the form of interconnectable modules for ease of transportation and erection on-site.



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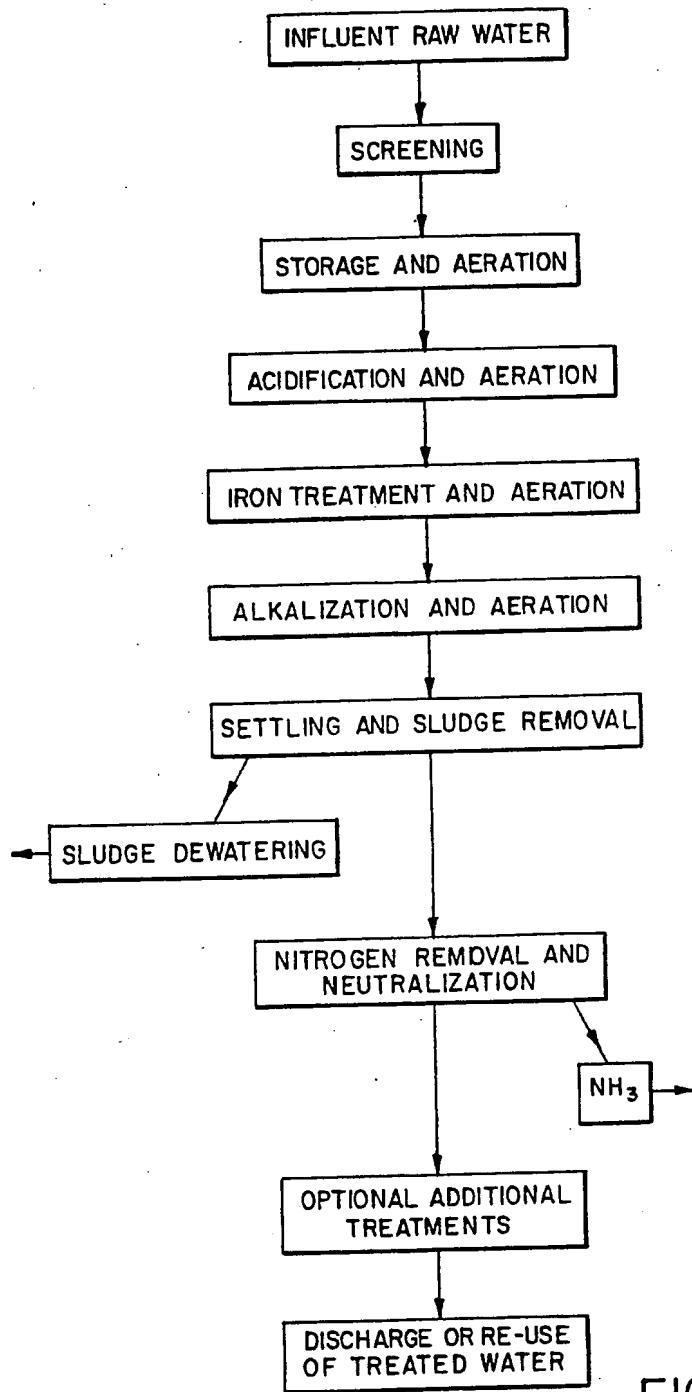


FIG. 1

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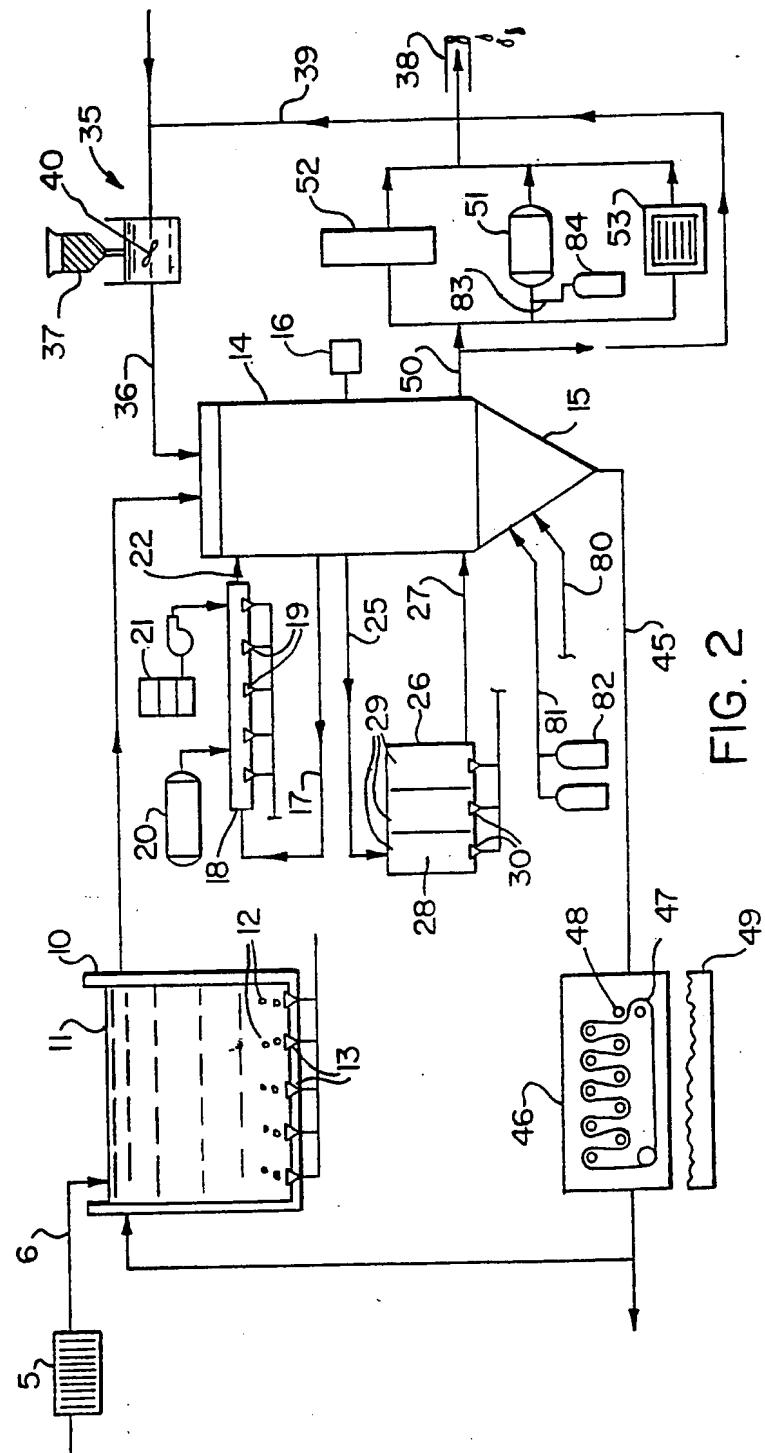


FIG. 2

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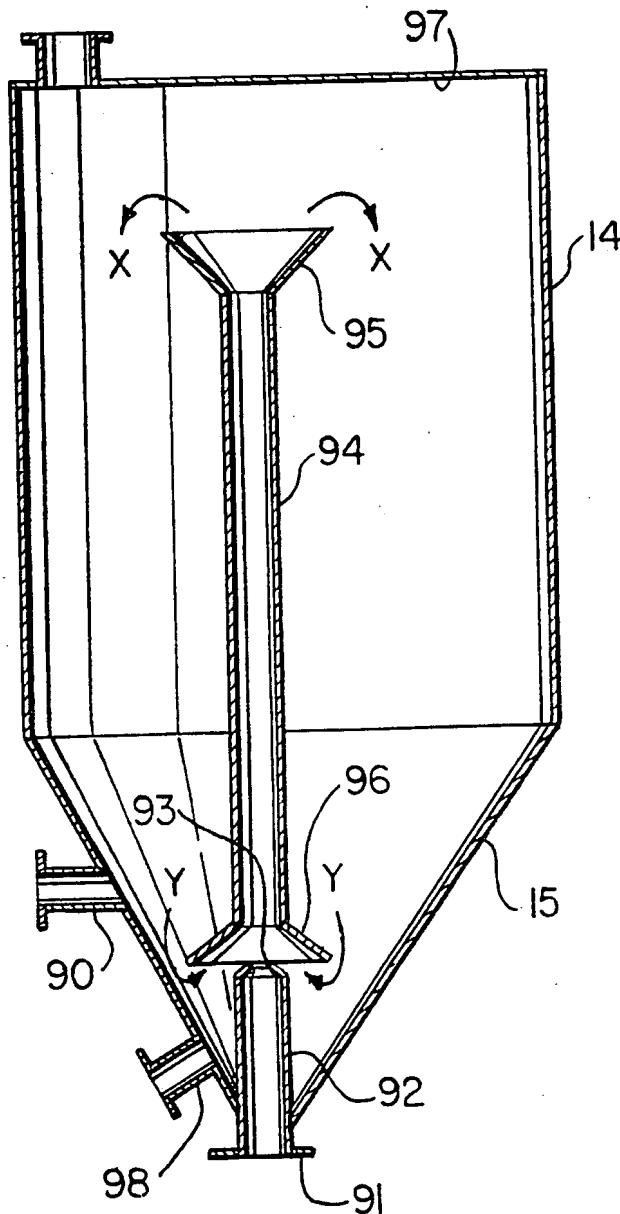
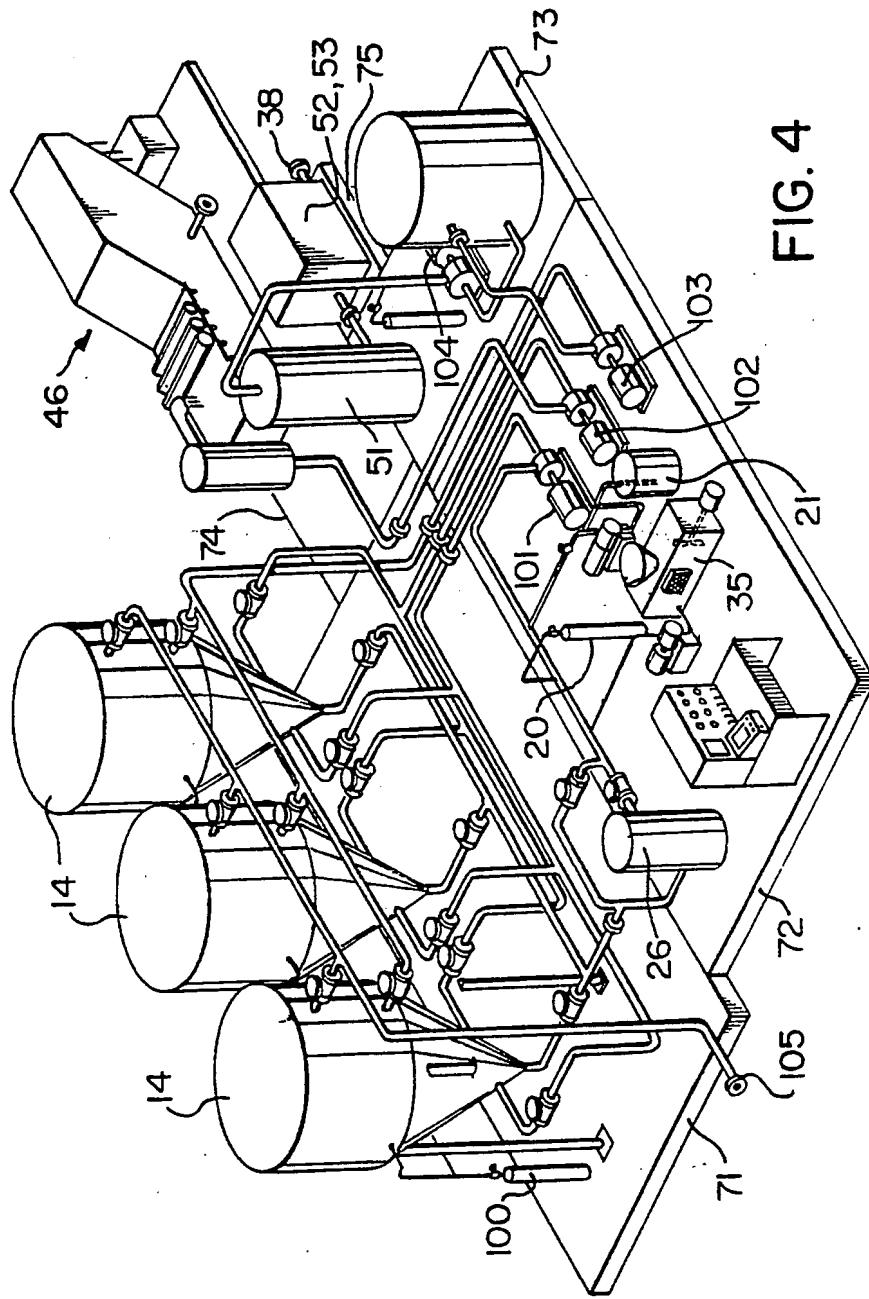


FIG. 3

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FIG. 4



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Process and apparatus for the purification of water

This invention relates to a process and apparatus for treating waste water so that it may be safely discharged into the environment or re-used.

The earth's water supply is in increasing danger these days because of pollution by mankind. This pollution takes various forms and includes the discharge of toxic chemicals by manufacturing plants, the discharge of raw sewage, and discharges of organic wastes from slaughter houses, farms and dairies, and such things as commercial laundry effluents. Many countries have standards governing the permissible nature of effluents and these regulations are likely to increase as more and more people become aware of the problems caused by the discharge of untreated waste waters and the like.

There is consequently an increasing need for processes and apparatus that can treat waste water from various sources in a manner which allows the water to be discharged into the environment without causing pollution.

Accordingly, an object of the invention is to provide such a process and apparatus.

According to one aspect of the invention there is provided a process for treating waste water, which comprises: acidifying the water to a pH of 3.5 or lower, contacting the acidified water with metallic iron, separating the water from the iron and rapidly making the water alkaline to a pH of 9.0 or higher; and separating the water from any precipitate or flocculate formed therein.

- According to another aspect of the invention there is provided apparatus for treating waste water, comprising means for adding acid to said waste water, means for contacting the acidified waste water with metallic iron, means for adding an alkali to said iron-treated waste water, a tank for holding said waste water to permit a precipitate or flocculate to settle therein and means for separating said precipitate or flocculate formed in said tank from said water.
- According to another aspect of the invention there is provided a kit for forming an apparatus for treating waste water, which comprises at least two apparatus modules each supported on a generally flat base, said modules being interconnectible to form an apparatus comprising means for adding acid to said waste water, means for contacting the acidified waste water with metallic iron, means for adding an alkali to said iron-treated waste water, a tank for holding said waste water to permit a precipitate or flocculate to settle therein, and means for separating said precipitate or flocculate formed in said tank from said water.
- According to yet another aspect of the invention there is provided apparatus for mixing a substance with a body of liquid, comprising a tank for holding said body of liquid, an upwardly directed water inlet adjacent to a bottom wall of the tank, a substantially vertically oriented elongated tubular member having an open upper end and an open lower end located above said liquid inlet to receive liquid entering said tank through said inlet, an outlet for liquid from said tank spaced from said inlet, pipe means interconnecting said inlet and said outlet, pump means for recirculating said liquid from said outlet to said inlet, and means for adding said substance to said pipe means, wherein said inlet and said open lower end of said tubular member are suitably spaced apart to generate a verturi effect causing liquid from said tank to enter said tubular member together with liquid entering said tank through said inlet.

The process and apparatus of the present invention is capable, at least in the preferred forms, of handling waste water from a number of sources, e.g. smaller municipalities, resorts, camps, hotels and motels, off-shore platforms, metal finishing establishments, slaughter houses, food processing facilities, laundry facilities, dairies, agricultural establishments, refineries, chemical process plants, and the like.

The invention, at least in the preferred forms, is capable of producing a high quality, clear product effluent and is capable of removing coliform and fecal coliform bacteria, suspended solids and reduces biochemical oxygen demand. The invention is also capable of, at least in preferred forms, reducing grease and oils, soluble calcium, sodium, chlorides, mercury, lead, iron, zinc, manganese, magnesium, cadmium, chromium, arsenic, colours or tints, etc., etc.

Preferred embodiments of the invention will be described in more detail below with reference to the accompanying drawings in which:

Fig. 1 is a flow diagram indicating the steps of a preferred process according to the present invention;

Fig. 2 shows a preferred apparatus for operating the process of Fig. 1;

Fig. 3 is a cross-section of a process tank suitable for use in the apparatus of Fig. 2; and

Fig. 4 shows alternative apparatus arranged in module form.

A preferred form of the process of the present invention is illustrated in schematic form in Fig. 1. The process of the present invention involves a batchwise operation rather than a continuous flow process and so discrete quantities of the raw water pass through the various steps of the process and are acted on in the manner indicated.

Influent raw waste water is preferably first screened to remove objects and matter that are too large to be processed and would otherwise cause operating problems in the system. The screened influent water is then desirably

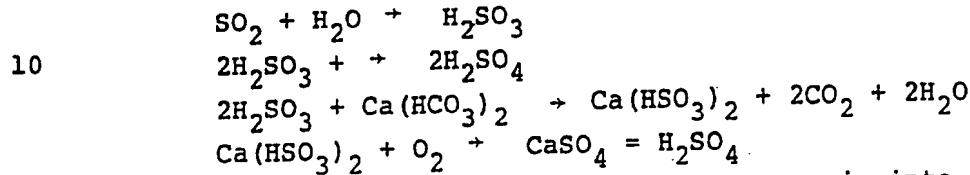
5 stored in a storage tank or holding pit where compressed air in the form of tiny bubbles is mixed into the bottom of the stored influent to increase the dissolved oxygen content, or, to achieve the same result, water from the storage tank is circulated through a trickling filter and then returned to the tank.

The air bubbling step has four basic advantages. Firstly, it is important to ensure that the influent water does not become generally anaerobic in nature as this increases the treatment required in subsequent processes and also eliminates other problems typically associated with septic sewage. Secondly, the multitude of tiny bubbles emitted into the bottom of the stored water keeps the suspended and settleable matter thoroughly mixed throughout the stored fluid. Thirdly, the continual addition of oxygen (air) promotes freshness in the waste water which enhances the subsequent removal of soluble organics in later stages of the process. Fourthly, the oxygen (air) entrained in the sewage is required for chemical reactions in subsequent steps of the process. Utilization of a trickling filter also provides these same benefits.

Once aeration is complete, the stored waste water is treated with acid to reduce the pH to 3.5 or below. The acidification step achieves several objectives. Firstly, it results in the formation of several chemical compounds required for subsequent flocculation, agglomeration and precipitation. The acidification step also results in the destruction of acid-sensitive bacteria and pathogenic organisms. The acid normally employed for the acidification step is sulfuric acid or sulfur dioxide. Waste water normally is mildly alkaline, often because of the presence of calcium bicarbonate and the acid neutralizes this alkalinity. Sulfuric acid combines with the calcium bicarbonate to form calcium sulfate and carbon dioxide:



In the case of sulfur dioxide, this combines with the water to form sulfurous acid which then combines with oxygen in the process stream to form sulfuric acid, which then reacts as above. Alternatively, or additionally, 5 the sulfurous acid may combine directly with the calcium bicarbonate to form calcium bisulfite and carbon dioxide. The calcium bisulfite then combines with oxygen to form calcium sulfate and sulfuric acid:



It is desirable to introduce oxygen or air into the influent raw water during the acidification step. The 15 oxygen or air increases the dissolved oxygen content which promotes the oxidation reactions indicated above and assists subsequent floc formation and reduction of organic levels.

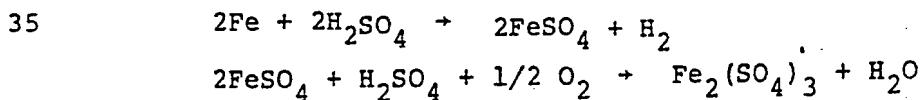
Sulfur dioxide gas can be classified as an oxidizing 20 agent. If sufficient sulfur dioxide gas is introduced into the influent water, and provided that sufficient contact time is maintained, the sulfur dioxide gas in itself makes an excellent disinfecting agent. The sulfur dioxide also reduces chlorine levels in the water. The 25 sulfur dioxide must be added in excess of any dissolved iron which may be in the process stream, as iron reacts with the free sulfur dioxide to create  $\text{FeSO}_3$ , which interferes with the disinfection process. Any residual dissolved sulfur dioxide remaining after the acidification 30 step may be stripped in later stages of the process, although this is usually not required because the sulfur dioxide normally reacts with the iron in the next stage of the process.

The amount of sulfuric acid and/or sulfur dioxide 35 added to the raw water is determined both by pH and by time considerations. The pH level is the main determinant

and sufficient acid is added to reduce the pH below the desired level. Once the desired pH level has been achieved, the further addition of acid is postponed. The pH should however continue to be monitored for a period of time required to ensure that proper acidification and mixing has taken place and that the pH does not rise above the minimal level. If the pH does increase, further acid is added. Typically, a time of approximately 5 minutes in excess of that amount of time which is required in practice to mix the solution is provided to allow for subsequent potential additional acid introduction.

The next step of the process involves contacting the acidified water with metallic iron usually in the form of particles of any suitable shape. The contact with the iron requires a certain minimum time which depends on the nature of the raw water and the pH imparted by the acidification treatment. Typically, the treatment time is 15 to 30 minutes. Scrap iron may be employed in this stage of the treatment and desirably the pieces consist of low carbon metal bars or sheets. So-called "Rebar" (reinforcing steel rods) is often used because of its effectiveness, cost and availability, but low carbon flat bar or sheets may also be employed.

The acidified water acts on the iron to produce soluble iron compounds, preferably in the trivalent state. When the acidifying agent is sulfuric acid or sulfur dioxide, ferrous sulfate or ferric sulfate are formed. If the water contains little dissolved oxygen ferrous sulfate type compounds (greenish floc) tend to become most prominent, and when dissolved oxygen is abundant, ferric sulfate type compounds (reddish floc) predominate. As in the previous acidification step, oxygen or air may be introduced into the process stream during the acidification step to promote the desired reactions, indicated as follows:



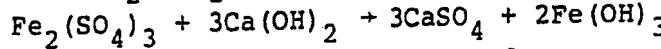
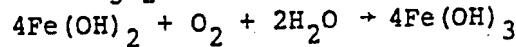
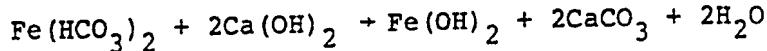
If any calcium bicarbonate is present during the acidification step, this may react with ferrous sulfate to form ferrous bicarbonate:



5 Iron is also useful for the removal of phosphate in the subsequent alkalization stage because iron reacts with lime to precipitate hydroxylapatite. Iron is also useful in reducing other industrial pollutants.

10 The next step of the process involves rapidly raising the pH of the water to 9.0 or above. The base employed to raise the pH is normally a slurry of calcium hydroxide. Preferably, fresh dry calcium hydroxide is added to water to a percentage of approximately 25% to 30% by weight and thoroughly mixed to form a slurry, and this lime slurry can be injected into the iron-treated water once the water has been removed from contact with the iron. As in the 15 acidification step, both pH and time dictate the amount of calcium hydroxide slurry to be added to the water. Slurry is added until the desired pH is achieved, the water and slurry are allowed to mix, and then a period of five minutes is allowed to elapse while the pH is monitored. If the pH falls below the desired minimum during this 20 time, further slurry is added to maintain the desired level. Air or oxygen can be added to the body of water, if desired.

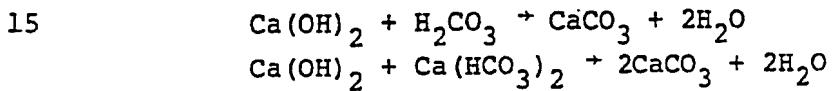
25 The addition of the lime initiates a number of reactions, e.g.:



30 Prior to the lime addition, the ferrous sulfate reacts with calcium bicarbonate to form ferrous bicarbonate and calcium sulfate. Once the calcium hydroxide is added, the ferrous bicarbonate reacts with the calcium hydroxide to 35 form ferrous hydroxide and calcium carbonate. The ferrous hydroxide is next oxidized to ferric hydroxide, which is

the ultimate compound desired. The ferric sulfate combines with calcium hydroxide to create calcium sulfate and ferric hydroxide. The ferric hydroxide forms a dense floc and ferric sulfate itself also forms a floc.

5           The oxidation indicated above is favoured by the higher pH values established by the addition of the lime slurry. The pH must be at least 9.0 and typically, the pH is between 10 and 11. The higher pH level is often necessary for the destruction of certain pathogenic and bacterial 10 constituents. Typically, more calcium hydroxide is added than is required for the precipitation of the iron and this calcium hydroxide combines with carbonic acid to form calcium carbonate. Calcium hydroxide plus calcium bicarbonate also forms calcium carbonate.



The calcium carbonate acts as a useful coagulant within the waste water.

20           Each particular waste water requires a proper dosage of lime. If too little is added, improper flocculation and clarification takes place. If too much calcium hydroxide is added, suspended organic matter will be dissolved into soluble form, and improper clarification results and the ultimate product is typically of a very 25 high turbidity and organic content.

Once sufficient calcium hydroxide has been added to achieve the desired pH, the processing of the influent water stops so as to allow agglomeration and coagulation and to allow subsequent precipitation of the coagulated matter in combination with suspended, settleable and dissolved organic and inorganic matter contained with the 30 waste water.

35           The next step of the process involves maintaining the waste water relatively quiescent so that settling of precipitates and flocculates may take place. The settling step normally takes from 45 minutes to 4 hours depending on the volume of the body of waste water and the nature of

the waste water being treated.

The sludge removed following the settling step is readily dewaterable by heat drying or by means of a conventional sludge dewatering process, or the like.

5 After sufficient settling time has elapsed, the clarified water is optionally treated for the reduction of nitrogen (as ammonia) from the waste water. This is accomplished by injecting compressed air into the waste water.

10 The final phase of the settling step is the reduction of the pH and hardness of the water. This is accomplished by the injection of carbon dioxide into the clarified water. Sufficient carbon dioxide is introduced to achieve the desired lower pH.

15  $\text{CO}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCO}_3$   
 $\text{CO}_2 + \text{CaCP}_3 + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{HCO}_3)_2$

Both pH and mixing time are again monitored to ensure the desired result. A further short settling period to allow solid calcium carbonate to settle is allowed and then the product effluent is either discharged or subjected 20 to additional treatments such as filtration and/or disinfection.

25 A particularly preferred additional treatment is bio-filtration. While the effluent following sludge removal will normally be devoid of most suspended solid matter and will also have much of the soluble organic and inorganic matter removed, soluble organic materials remaining within the effluent can be further reduced by biofiltration. The biofiltration step first consists of the addition of pure oxygen or air to increase the dissolved oxygen content in 30 the product to a predetermined level. This level is normally within the range of 25-50 milligrams of oxygen per litre of product effluent. The use of pure oxygen is preferable to the use of air because smaller quantities are required, especially as pure oxygen is much more soluble than is the oxygen within atmospheric air. Sufficient time 35 for retention and/ or pressures are required to ensure the total absorption of the dissolved oxygen within the product effluent stream.

The biofilter employed is usually a multi-media filter wherein the largest media layer comprises expanded clay or expanded shale. These substances have very high surface areas. A typical media size is 2.0 mm to 15.0 mm. Aerobic and anaerobic layers quickly develop throughout the filter media and, as the oxygen-rich effluent passes by them, the soluble organic material is reduced by microbiological processes. The filter is also useful in reducing additional amounts of suspended solids within the waste water and is effective in reducing nonorganic suspended and dissolved materials or compounds. The filter may be monitored by a pressure or turbidity sensing method and once sufficient back pressure or increased turbidity in the product is detected, a back wash cycle is initiated so as to clear the filter media of excessive debris and film. The final water product water can then be discharged into the environment or re-used.

Fig. 2 shows a preferred apparatus for carrying out the process described above.

Influent raw waste water is first screened through a conventional commercial screen 5 which may be, for example, a climbing bar screen. The screened effluent is then passed through pipe 6 and preferably into a storage tank 10 to form a body of water 11. The storage tank 10 may be made of a suitable corrosion-resistant metal or may be in the form of a holding pit lined with an impervious and corrosion-resistant liner (not shown). Aeration of the body of water 10 takes place in the tank 10 by the introduction of air 12 via nozzles 13. The air is supplied by compressing atmospheric air with a compressor (not shown). If the ambient atmospheric air temperature is less than 50°F, it is preferably preheated before compression and injection into the waste water. The nozzles 13 emit tiny bubbles in a wide pattern throughout the entire tank 10, preferably at the bottom of the tank where the pressure head is greatest. Water 11 may also (or alternatively) be cycled through a roughing trickling filter (not shown).

preferably located on top of tank 10. The water would be supplied to the trickling filter and returned by gravity to tank 10. The roughing trickling filter enhances aeration and soluble organic reduction in instances where this is required. After sufficient aeration has been carried out, the raw water is transferred to a main process tank 14 having a cone-shaped bottom 15 and provided with a pH monitor 16. The transfer is effected by a sewage handling pump (not shown), preferably a non-clog electrically powered and controlled grinder pump or macerator pump which reduces the larger solids to a more processable size and also allows for more complete reaction and bacterial kill in subsequent process steps. Enough waste water is pumped to fill the process tank 14 preferably to between 150 and 400 mm of the top of the process tank (depending on the characteristics of the water being treated, the site of the tank and the tank design). Once the desired level has been achieved (determined either manually by an operator, by pumping time, or by level sensing devices), the sewage pump is turned off.

The acidification step is then carried out on the water in tank 14 by withdrawing water from the tank via pipe 17 and passing it through an aeration and acidification chamber 18. This is achieved by using a process pump (not shown), preferably a non-clog corrosion-resistant pump capable of handling abrasive liquids whose pH values may vary from pH 2.0 to pH 11.5, and typically is capable of pumping about 5% of the volume of the process tank 14 per minute (plus or minus 2.5%) normally at a pressure of 20-40 psi, although the pressure is a function of tank size, design flows, design characteristics and whether it is a pressure tank or an atmospheric tank. Air is preferably introduced into chamber 18 through nozzles 19 and sulfur dioxide is introduced from cylinder 20 and/or sulfuric acid is introduced from tank 21. The treated water is then recirculated to tank 14 via pipe 22. The water is recirculated until the pH monitor 16 indicates

that the pH of the water in the tank 14 has dropped to the desired level. As indicated above, the pH may be monitored for a further period of time and extra acid added if the pH rises above the desired level. The management of acid  
5 and/or sulfur dioxide addition may be carried out either manually, automatically or semi-automatically.

Following the acidification step, or throughout certain portions of the acidification step depending on the time frame of the acidification step and the amount of iron required for floc formation and constituent reduction, the iron treatment step is commenced. To achieve this, water is withdrawn from tank 14 through pipe 25, passed through an iron treatment chamber 26 and recirculated to tank 14 via pipe 27. The chamber 26 contains iron particles 28 or pieces of various shapes in several compartments 29 and the water is caused to flow in a serpentine manner from one compartment to another in order to achieve good contact with the iron. Aeration of the water takes place via nozzles 30. As noted above, the iron treatment is carried out for a certain period of time, normally 15 to 30 minutes depending upon flow rates and volumes. However, the time period should be sufficient to have sufficient iron concentrations to permit suitable floc formation in subsequent steps. The iron chamber 26 is normally a corrosion-resistant pressure vessel or vessels of non-clog design mounted on a manifold of piping. Preferably, the chamber has a number of modules (not shown) which screw or clamp via couplings into the chamber, and each module contains a particular number of iron rods or pieces of predetermined length and width. This allows for easy maintenance of the iron chamber in that an operator may readily exchange used modules at pre-determined times. The exact area of iron exposed in the chamber is a direct function of the flow of water through the chamber, the desired time frame within which the dissolved iron level is to be achieved and the specific waste water being treated. Typically the required iron concentration should vary from 5.0 ppm to 100.0 ppm.  
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5        The amount of air introduced during the iron treatment step (and indeed the other steps) may in some cases be critical. Insufficient air will not promote the desired reactions, however too much air will create large bubbles of expanding air which cause vibration and mixing problems and as well may affect the settleability of the floc.

10      After the water has been recirculated through the iron treatment chamber 26 for a suitable time, the recirculation is terminated and valves (not shown) are operated to seal off chambers 18 and 26 from the tank 14 and the alkalization step is commenced. A lime slurry is added to the tank 14 from a mixing apparatus 35 via pipe 36. The mixing apparatus forms the slurry from lime powder 37 and water (normally taken from the apparatus discharge 38 via pipe 15 39). The mixing is effected by a stirring device 40. Sufficient lime is added to raise the pH to the desired value, normally pH 10.0 to 11.0, as indicated on the monitor 16. Again, the pH is monitored for a period of time and further lime added if the pH falls below the 20 desired level.

25      After the lime addition, the solids (sludge) formed through flocculation, coagulation, or agglomeration in tank 14 are allowed to settle to the cone-shaped bottom 15 of the tank and are withdrawn, either continuously or intermittently, through pipe 45 and de-watered in either a de-watering apparatus 46 having an endless conveyor 47 acted upon by rollers 48 or by a plate press (not shown) which compresses sludge, to dewater it, between filter plates. The rollers or plates compress the solids and 30 these are further dried by heat from a heat source 49. The dried solids can be discharged or, if desired, recirculated to storage tank 11. The removal of the solids can be directed visually by an operator of the apparatus, by a time process or by the use of sludge sensors or turbidity meters. The sludge blanket level in tank 14 should of course be maintained below the clarified water outlet 35 (normally about half a meter from the bottom of the tank).

Nitrogen in the clarified water may be removed as ammonia by injecting compressed air into the process tank 14 at specific points via pipe 80 to cause stripping of the ammonia from the high pH liquid.

5       The final stage of the settling step is the reduction of the pH to approximately pH 7, and desirably the reduction of the water hardness. This is accomplished by injecting CO<sub>2</sub> into the treated water in the lower regions of the process tank 14 via pipe 81 from cylinders 82 or  
10      from compressed combustion off gases generated during the optional heat drying of sludge. The CO<sub>2</sub> introduction is again governed by pH (monitored via sensor 16) and time and a further short settling period is allowed to permit precipitated calcium carbonate to settle.

15      The clarified water in tank 14 remaining after settling has taken place is withdrawn via pipe 50 and either passed directly to the discharge 38 or first passed through any one or more of a biofilter 51 (as described earlier), an activated carbon filter 52 or a disinfection apparatus 53.  
20      When the biofilter 51 is employed, oxygen is first injected into the water flow via pipe 83 from cylinder 84. The activated carbon filter 52 and disinfection apparatus 53 may be conventional.

25      Naturally, instead of a single process tank 14, several may be provided to increase the capacity of the treatment plant, each tank being individually connected to chambers 18 and 26, mixing apparatus 35, de-watering apparatus 46, filters 51 and 52, disinfection apparatus 53 and outlet 38, for treatment of the raw water in the manner indicated above.

30      As an alternative to the apparatus shown in Fig. 2, a similar apparatus (not shown) may be provided in which water 11 from tank 14 passes directly to pipe 17 without first entering tank 14. From pipe 17 the water passes through the aeration and acidification chamber 18 and is acidified as previously described with sulfur dioxide

and/or sulfuric acid. An additional pH monitoring apparatus is connected to chamber 18 to monitor pH values as the acid is added. The acidified water then leaves chamber 18 via pipe 22 which takes it directly to pipe 25 without entering tank 14. The water travels through iron treatment chamber 26 and then to tank 14 via pipe 27. Pipe 22 and pipe 27 normally join to form a single pipe and it is this pipe that enters tank 14. A valve is advantageously provided to prevent backflow up either pipe 17 or pipe 5 when undesired. In this alternative form of the apparatus, iron treatment tank 26 may not necessarily be a pressure vessel and may be a non-pressure vessel with several compartments which again cause the water to flow in a serpentine manner from one compartment to another to achieve good contact with the iron in the compartments or with the sheets of iron that separate these compartments. These sheets of iron can also be replaced as and when they are used up or at predetermined times. Typically these sheets are loaded into chamber 26 to sit in predetermined slots that are provided in the external housing of chamber 26. The other parts of this alternative apparatus may be the same as the other parts of the apparatus shown in Fig. 2.

The process tank 14 preferably has an internal design as shown in cross section in Fig. 3. An outlet 90 is provided near the bottom of the conical section 15 of the process tank 14 and an inlet 91 is provided at the apex of the conical bottom section. The inlet 91 has a tubular extension 92 which projects into the interior of the tank for a short distance along the central tank axis. The upper end of the tubular extension 92 has an outlet 93 of reduced area compared to the internal cross-sectional area of the extension over the remainder of its length. A hollow vertical tubular member 94 is mounted within the tank along the central tank axis and it is provided with

outwardly flared ends 95, 96. The upper flared end 95 is located a short distance below the top 97 of the tank and the lower flared end 96 is located a short distance above the outlet 93 of the tubular extension 92. However, the position of the tubular member 94 is vertically adjustable so that the spacing between the outlet 93 and the flared end 96 is variable. Accumulated sludge is removed via tubular member 98.

During the acidification, iron treatment and preferably even the alkalinization steps of the process, water from the tank is recirculated between outlet 90 and inlet 91 and, while the water is outside the tank, it is contacted with the acid, iron or alkali. When the treated water returns to the tank through inlet 91 it enters the tubular extension 92 and accelerates as it passes through the outlet 93. As a result, a jet of water is forced into the central tubular member 94 and passes upwardly through the member and out of the upper flared end 95 into the upper region of the tank as indicated by arrows X. Water in the lower region of the tank is drawn into the lower flared end 96 of the tubular member 94 by a "venturi effect" as indicated by arrows Y. The amount of water drawn into the tubular member in this way depends on the flow speed and volume of the water ejected from outlet 93, the spacing between the tubular extension 92 and the lower flared end 96 and the free area between the tubular extension and the lower free end. Since the spacing between the tubular extension 92 and the lower flared end 96 is adjustable, the amount of tank water recirculated through the tubular member 94 can be varied at will.

As described earlier, in an alternative form of the apparatus to that shown in Fig. 2, water 11 from tank 10 is acidified and contacted with iron before it enters tank 14, in which case it enters through inlet 91 and tubular extension 92. In this case, water is not withdrawn through outlet 90 but instead the tank design ensures that water

entering tank 14 mixes thoroughly with water already in the tank. Water may also be introduced into tank 14 in this way in certain instances even in the design of apparatus shown in Fig. 2.

5       The advantage of the tank structure described above is that rapid mixing of treated water entering inlet 91 and water already within the tank takes place without causing vigorous eddy currents within the main body of water in the tank. Consequently, flocs and deposits forming within  
10      the tank are not violently disturbed and are free to settle in the peripheral regions of the tank towards the tank bottom. The water exiting the upper flared end 95 of the tubular member as indicated by arrows X has lost most of its initial kinetic energy and gently descends to the  
15      bottom of the tank outside the tubular member. On the other hand, rapid and complete mixing of the water takes place in the lower part of the tubular member 94 by virtue of the confluence of the water indicated by arrows Y and the water ejected from outlet 93. The tubular member 94 thus serves to isolate an area of rapid liquid mixing and movement within the member from a relatively quiescent zone outside the member.

25      Desirably, the various components of the apparatus are produced in separate modules for easy transportation and erection on-site. An example of the manner in which this can be arranged is shown in Fig. 4. The apparatus is divided into five sections or modules which can be transported separately and readily connected together. The sections are mounted on pallets 71, 72, 73, 74 and 75  
30      which act as supports for the modules during manufacture and transportation and as foundations for the apparatus on-site. The use of such pallets means that site preparation is minimized and can be confined to suitable leveling and stabilization (e.g. by providing a layer of crushed stone).

35      Alternatively, the pallets 71, 72, 73, 74 and 75 may be mounted on a proper foundation, e.g. made of concrete, and this foundation may be used to form a large water tank

to act as tank 10, in which case water inlet pipe 105 may pass through one of the pallets and into the tank located below it.

Pallet 71 forms a tank module holding three process tanks 14, a CO<sub>2</sub> tank 100 and the various interconnecting pipes and valves. Pallet 72 forms a process module holding iron tank 26, an SO<sub>2</sub> cylinder 20, a sulfuric acid tank 21, lime mixing apparatus 35, a pump 101 for recirculating the water during the acidification, iron and alkalinization steps, a pump 102 for removal and discharge of sludge and a pump 103 for removing and transferring clarified process water. Pallet 73 forms a filtration module holding a bio-filter 51, an oxygen cylinder, a pre-filter holding tank and a liquid transfer pump 104. Pallet 74 forms a sludge processing module holding solids de-watering apparatus 46.

Pallet 75 forms a water polishing module holding, for example, an activated charcoal filter 52 and/or disinfection apparatus 53, as well as the product water discharge 38.

If desired, additional pallets 71 may be provided (together with necessary connecting equipment) to increase the water treatment capacity of the equipment and/or the pallet 71 may be made larger to accommodate more tanks.

The modules are all interconnected via standard pipe couplings and the pallets can be bolted together and/or to the ground or foundation if desired. The use of modules in this way means that the apparatus can be sold essentially in "kit" form. Preferably the modules are such that they can all be mounted on a single transporter for ease of delivery to the site of intended use.

Although preferred embodiments of the invention have been described in detail above, it will be apparent to persons skilled in the art that various modifications and variations are possible without departing from the scope of the invention as defined by the following claims. All such variations and modifications form part of the present invention.

Claims:

1. A process for treating waste water, which comprises:
  - acidifying the water to a pH of 3.5 or lower,
  - contacting the acidified water with metallic iron,
  - separating the water from the iron particles and

5 rapidly making the water alkaline to a pH of 9.0 or higher; and

separating the water from any precipitate or flocculate formed therein.
2. A process according to Claim 1 wherein the water is acidified by mixing it with sulfuric acid.
- 10 3. A process according to Claim 1 wherein the water is acidified by mixing it with sulfur dioxide.
4. A process according to Claim 1, Claim 2 or Claim 3 wherein the water is aerated as it is being acidified.
- 15 5. A process according to Claim 1, Claim 2 or Claim 3 wherein the pH is reduced to the range of pH 2 to pH 3.5.
6. A process according to Claim 1 wherein the acidified water is aerated as it is being contacted with the iron.
7. A process according to Claim 1 wherein the acidified water is contacted with the iron for a period of time of about 15-45 minutes.
- 20 8. A process according to Claim 1, Claim 6 or Claim 7 wherein the iron is in the form of particles made of low carbon iron.
- 25 9. A process according to Claim 1 wherein the iron-treated water is made alkaline by mixing it with an aqueous slurry of lime.
10. A process according to Claim 1 wherein the iron-treated water is made alkaline to the extent that the pH of the water falls into the range of about pH 9 to pH 11.
- 30 11. A process according to Claim 1, Claim 9 or Claim 10 wherein the iron-treated water is aerated as it is being made alkaline.
12. A process according to Claim 1, Claim 2 or Claim 3 wherein the waste water is screened to remove large solid particles before the water is acidified.

13. A process according to Claim 1, Claim 2 or Claim 3 wherein the waste water is aerated to increase the content of dissolved oxygen before the water is acidified.
- 5 14. A process according to Claim 1, Claim 2 or Claim 3 wherein the water is separated from any precipitate or flocculate by allowing the water to remain quiescent after the alkalization step so that any contained solids settle to the bottom and removing the settled solids from the water.
- 10 15. A process according to Claim 1, Claim 2 or Claim 3 wherein, after the alkalization step, nitrogen is removed from the water by bubbling air through the water to remove any dissolved ammonia.
- 15 16. A process according to Claim 1, wherein the water is neutralized after the precipitate or flocculate has been removed therefrom.
17. A process according to Claim 16 wherein the water is neutralized by the addition of a suitable quantity of carbon dioxide gas.
- 20 18. A process according to Claim 1, Claim 2 or Claim 3 wherein, following the removal of said precipitate or flocculate, the waste water is passed through a bio-filter.
19. A process according to Claim 1, Claim 2 or Claim 3 wherein, following the removal of said precipitate or
- 25 25. flocculate, the waste water is subjected to a treatment selected from the group consisting of disinfection and treatment with activated carbon.
20. Apparatus for treating waste water, comprising means for adding acid to said waste water, means for contacting the acidified waste water with metallic iron, means for adding an alkali to said iron-treated waste water, a tank for holding said waste water to permit a precipitate or flocculate to settle therein and means for separating said precipitate or flocculate formed in said tank from said water.

21. Apparatus according to Claim 20 wherein the apparatus includes means for removing water from said tank and for recirculating said removed water back to said tank, and wherein said means for adding acid adds said acid to said removed water.
- 5
22. Apparatus according to Claim 20 wherein the apparatus includes means for removing water from said tank and for recirculating said removed water back to said tank, and wherein said means for contacting the acidified waste water with metallic iron acts on said removed water.
- 10
23. Apparatus according to Claim 20 wherein the apparatus includes means for removing water from said tank and for recirculating said removed water back to said tank, and wherein said means for adding an alkali to said iron treated waste water adds said alkali to said removed water.
- 15
24. Apparatus according to Claim 20 wherein the means for separating a precipitate or flocculate from said water comprises means for withdrawing solids settled at the bottom of said tank from said tank.
- 20
25. Apparatus according to Claim 24 wherein said tank has a downwardly tapering cone-shaped bottom and wherein said means for withdrawing settled solids has a solids outlet adjacent to a lowermost part of said cone-shaped bottom.
26. Apparatus according to Claim 20, Claim 21 or Claim 22 further includes one or more additional means for the treatment of the water remaining after the removal of any precipitate or flocculate formed therein, said additional means being selected from the group consisting of a bio-filter, activated carbon and a disinfection apparatus.
- 25
27. Apparatus according to Claim 20, Claim 21 or Claim 22 wherein the means for adding acid to said body of waste water includes means for aerating the water.
- 30
28. Apparatus according to Claim 20, Claim 21 or Claim 22 wherein the means for contacting the acidified waste water with metallic iron includes means for aerating the acidified water.
- 35

29. Apparatus according to Claim 20, Claim 21 or Claim 22 wherein the means for adding alkali to said iron-treated waste water includes means for aerating said iron-treated waste water.
- 5       30. Apparatus according to Claim 20, wherein said tank for holding a body of said waste water has an upwardly-directed water inlet adjacent to a bottom wall of the tank, a substantially vertically oriented elongated tubular member having an open upper end and an open lower end located above said water inlet to receive water entering said tank through said inlet, an outlet for water from said tank spaced from said inlet, pipe means interconnecting said outlet and said inlet and pump means for recirculating said water from said tank, via said pipe means to said inlet, said inlet and said open lower end of said tubular member being suitably spaced apart to generate a venturi effect causing water from said tank to enter said tubular member together with water entering said tank through said inlet.
- 10      15      20      31. Apparatus according to Claim 30 wherein the position of said tubular member within said tank is adjustable to enable said venturi effect to be modified.
- 25      32. Apparatus according to Claim 20, Claim 21 or Claim 22 wherein said means forming said apparatus can be separated into at least two interconnectible modules and wherein said modules are each supported on a generally flat base member.
- 30      33. A kit for forming an apparatus for treating waste water, which comprises at least two apparatus modules each supported on a generally flat base, said modules being interconnectible to form an apparatus comprising means for adding acid to said waste water, means for contacting the acidified waste water with metallic iron, means for adding an alkali to said iron-treated waste water, a tank for holding said waste water to permit a precipitate or flocculate to settle therein, and means for separating said precipitate or flocculate formed in said tank from said water.
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34. Apparatus for mixing a substance with a body of liquid, comprising a tank for holding said body of liquid, an upwardly directed water inlet adjacent to a bottom wall of the tank, a substantially vertically oriented elongated tubular member having an open upper end and an open lower end located above said liquid inlet to receive liquid entering said tank through said inlet, an outlet for liquid from said tank spaced from said inlet, pipe means interconnecting said inlet and said outlet, pump means for recirculating said liquid from said outlet to said inlet, and means for adding said substance to said pipe means, wherein said inlet and said open lower end of said tubular member are suitably spaced apart to generate a verturi effect causing liquid from said tank to enter said tubular member together with liquid entering said tank through said inlet.

10 35. A process for treating waste water, substantially as hereinbefore described with reference to the accompanying drawings.

15 36. Apparatus for treating waste water, substantially as hereinbefore described with reference to the accompanying drawings.

37. A kit for forming an apparatus for treating waste water, substantially as hereinbefore described with reference to the accompanying drawings.

38. Apparatus for mixing a substance with a body of liquid, substantially as hereinbefore described with reference to the accompanying drawings.